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Biogas: A promising renewable technology and its impact on rural households in Nepal

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ABSTRACT

Nepal, one of the least developed countries, is characterized by very low per capita energy consumption. Because of a lack of other commercial sources of energy, the country relies heavily on traditional fuel source, especially firewood. In order to solve the energy problem in rural areas, the country initiated production and distribution of several renewable energy technologies. Among several technologies, biogas has been proved to be viable and emerged as a promising technology. It has been one of the most successful models for the production of clean, environmental friendly, cost effective source of energy and has multiple benefits. In this paper we present the current state and discuss benefits of the biogas technology in Nepal. Improved health, increased crop productivity, saved time for women are some of the major benefits to the users. It provides economic benefit to the country through reduced deforestation and carbon trading. In addition, by reducing green house gas emission, the technology helps in mitigating global warming and climate change. Thus biogas is a renewable, sustainable and clean source of energy that provides multiple benefits; locally and globally. With some exception, cattle dung has been used primarily as an input and the technology is limited to households only. More systematic and comprehensive study supported by research and development is required to use other degradable waste such as municipal waste to produce biogas on a large scale.

Contents

1. Introduction

Energy is one of the basic inputs for all economic activities. Per capita energy consumption is one of the major determinants as well as indicator of economic development. In other words, per

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capita energy consumption and economic growth reinforce each other [1–3].[1] Thus, lack of affordable and reliable energy hampers economic development. Nepal, one of the least developed countries, is characterized by low energy consumption and is among the lowest per capita energy consuming countries in the world. According to World Resource Institute [4], Nepal's per capita energy consumption for the year 2005 was 338 kgoe,[2] which is very low as compared to the average for other Asian countries (1051.5 kgoe) and the worldwide average (1778 kgoe).

Nepal has a huge potential of hydroelectricity. However, because of technical and financial constraints, the country has not been able to tap the potential of water resources. Forests, which are main resource of biomass energy, have already been exploited beyond their sustainable capacity and are becoming relatively scarce. Since no significant reserves of petroleum and coal have been discovered in Nepal, the country has to import petroleum from other countries. Given the diverse hilly and mountainous topography, increasing oil prices, high health risk associated with unsustainable firewood burning and high infrastructure cost associated with hydroelectricity production, it was necessary for the government to consider other alternatives which are sustainable and affordable. In order to solve the energy problem in rural areas, the government of Nepal initiated production and distribution of several Renewable Energy Technologies (RETs) such as micro hydro, solar, wind and biogas. As a result, the country has made significant progress in RETs. Among several other RETs, biogas has been proved to be viable and emerged as a promising technology especially, for rural households. Moreover, it has been one of the most successful models for the production of clean, environmental friendly and cost effective energy. Biogas in Nepal has offered several benefits to the country such as health, environmental, agricultural and economic benefit.

Several studies such as Omer and Fadalla [5], Prasertsan and Sajjakulnukit [6], and Yu et al. [7] discuss potential of biomass energy as an alternate source of energy and review the ecological, social, cultural and economic impacts of biogas technology. Perhaps more relevant, Pokharel [8] and Gautam et al. [9] present the current state and potential of biogas production in Nepal. Pokharel [8] discusses Nepal's current contribution to Green House Gas (GHG) emission and the potential of different RETs for GHG emission reduction. According to Gautam et al. [9], the biogas has helped the nation in many ways through income generation, life style improvements and cost saving. The authors also discuss different types of benefits of biogas such as health, education, employment generation, reduction in fuel consumption etc. However, the paper does not explicitly quantify these benefits. Despite its multiple benefits for the empowerment of rural households, there is dearth of studies which assess the social and economic benefits of the biogas in Nepal. This study attempts to fill this gap by assessing the impacts of biogas to the rural households in Nepal using qualitative as well as quantitative methods.

In this paper we highlight the present scenario of biogas energy, assess benefits of biogas and discuss future challenges. More specifically, we attempt to answer the following:

- Is there improvement in the health conditions of the household members after the installation of biogas, if so, to what extent is the technology able to impact the health conditions?
- How does the biogas impact the agricultural sector? Is it helpful in increasing the income of the users after the biogas installation?
- What are the environmental impacts of biogas in Nepal? Has it been helpful in reducing deforestation?
- Does biogas in Nepal contributes in GHG emission reduction?
- To what extent has the technology been successful in reducing the workload from household activities such as firewood collection, cooking etc? Are women the prime beneficiaries of the technology?

Using Biogas User Survey 2007/2008, we answer these questions by assessing health, agricultural, environmental impacts of biogas in Nepal. We also discuss the impact of biogas on GHG emission reduction. The rest of this paper will proceed as follow. We present current status of energy consumption and historical background of biogas in Nepal in Sections 2 and 3 respectively. In Section 4 we assess the benefits of biogas using the data from Biogas User Survey 2007/2008. In Section 5, we discuss challenges and future directions for the biogas. We conclude in Section 6.

2. Current status of consumption of energy and biogas technology in Nepal

Nepal is blessed with many rivers and tributaries, and consequently with huge potential of hydroelectricity. Despite this huge potential (43 000 MW), total hydroelectricity produced by the end of the year 2006/2007 was 560 MW [10]. Of the total population, 86% of Nepalese live in rural areas, and only 27% have access to electricity [11]. Thus, there is a lack of electricity for basic domestic and social uses such as cooking and lighting.

2.1. Current status of energy consumption in Nepal

Total energy consumed in the year 2006/2007 was 7 160 000 TOE. Energy resources in Nepal can be divided into three broad categories; traditional, commercial, and renewable. Traditional sources include fuel wood, agricultural residues and animal waste. Hydroelectricity and petroleum are commercial sources. Because of the lack of enough commercial sources, the country relies heavily on traditional energy (84%). As shown in Fig. 1, 15% of the energy was provided through commercial sources while less than 1% (0.7%) of the total energy consumed was renewable [10].

Of the total energy consumed in the country, firewood constituted 72% followed by cattle dung (7%), and agriculture residue (5%) [10]. Electricity is the major commercial source of energy (10%) followed by coal and petroleum. We present, in Table 1, the consumption of energy by fuel type in the year 2006/2007.

In terms of sector wise consumption, about 90% is consumed by residential sector [12]. About 96% of the residential energy consumed is met through traditional sources followed by commercial (3.6%) and renewable (0.6%). Thus, residential sector is the major energy consuming sector and most of it is met through traditional sources. Among traditional, fuel wood is the biggest source.

2.2. Biogas: a potential source of energy

The dependence of firewood as major source of energy has resulted in the deterioration of forests and various problems associated with it such as deforestation, erosion, etc. In addition, use of firewood causes several health problems such as an increase in eye infection and respiratory diseases. More time required for firewood collection is another problem associated with the use of firewood. Thus, lack of other commercial energy and problems

[1] For example Kraft and Kraft [1] and Aqeel and Butt [2] found that the increase in energy consumption is caused by increase in GNP. Lee et al. (2008), using data from 16 Asian countries, found that long-run economic growth is caused by increased energy consumption.

[2] 1000 kgoe = 42 GJ.

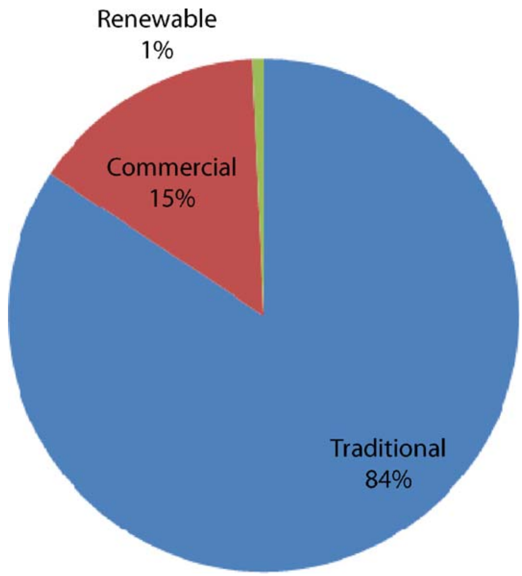


Fig. 1. Energy consumption by fuel type in Nepal (2006/2007).

Table 1
Energy consumption by fuel type in Nepal (2006/2007), 1000 TOE.

Fuel type		Consumption	Percentage
Traditional	Fuel wood	5187	72.4
	Agriculture residue	349	4.9
	Animal dung	501	7.0
	Subtotal		84.3
Commercial	Petroleum products	172	2.4
	Electricity	706	9.9
	Coal	194	2.7
	Subtotal		15.0
Renewable		51	0.7
Total		7160	100.0

Source: Economic Survey of Nepal 2007/2008.

associated with the use of biomass has impelled the country to outline alternative policies with regard to energy supply, especially for rural households. As a result, significant effort has been put for the production of more cleaner and sustainable form of RETs. Biogas has emerged as a promising technology and proved to be one of the most successful models among several other RETs in Nepal.

More than 80% Nepalese live in rural area and agriculture is the primary source of livelihood for most of these people [10]. Moreover, agriculture in Nepal is characterized by crop production and animal husbandry. Animal husbandry which is common in most of the rural households provides input for the biogas technology. Biogas is a simple technology in which cattle residue (dung) is used in an airtight underground digester to produce methane which is then connected to kitchen for cooking or lighting. It produces 50–60% methane and 40–50% carbon dioxide and some other gases [13]. It burns with blue flame without emitting smoke and is CO_2 neutral. It converts agricultural and livestock waste into clean energy and fertilizer. On average, a 6 m^3 of digester requires 36 kg of dung and same amount of water, which is sufficient for a stove to be used for 3.5 h. Because of its agricultural dominance and livestock farming, Nepal has huge potential of biogas. Based on the animal population, there is potential for installing 1.9 million family sized[3] biogas plants in Nepal [13].

[3] Among four common types of family size biogas plants (4, 8, and 10 m^3) installed in Nepal, 6 m^3 are most common.

Table 2
Biogas plants installed in Nepal.

Year/phase	Biogas plants installed
First phase (1992–1994)	6824
Second phase (1994–1997 March)	13,375
Third phase (March 1997–June 2003)	91,196
Forth phase (July 2003–June 2009)	63,196
Total	174,591

Source: BSP 2009.

3. Historical background and current status of biogas in Nepal

Biogas was first introduced to Nepal in the year 1955. After its recognition as a feasible technology and realizing the importance, Gober Gas Company (GGC) was established in 1977 by the government of Nepal for the promotion and dissemination of biogas. Since the number of biogas installed prior to 1985 was not significant, the government decided to provide a subsidy of 25% on the capital cost and 50% on the interest payment to meet the target of 800 units per year [13]. Realizing the significance of the technology, the Biogas Support Program (BSP)[4] was initiated in 1992 to develop and promote the use of biogas in Nepal. Large-scale use of biogas began in 1992 with the formation of the Biogas Support Program (BSP). To popularize and promote RETs, Alternative Energy Promotion Center (AEPC) was established in 1997 under the Ministry of Science and Technology [8]. The project has completed its 3 phases successfully and currently running on phase IV. Table 2 provides total number of biogas installed in the 4 different phases in Nepal.

During the first phase, 6824 biogas plants were successfully installed [14]. Since then, the number of biogas installed has been continuously increasing. In total, 189 122 biogas plants have been installed in 66 of the nation's 75 districts. Under phase IV, 135 000 plants are being installed.

4. Benefits of biogas in Nepal

Generation of direct as well as indirect benefits to individual and the society is the reason behind the success of biogas in Nepal. The biogas in Nepal has local, national as well as global impacts. As local benefits, it has brought households, smoke and ash free kitchen and made cooking easier, faster and healthier. Reduced time in searching for firewood is another benefit. In addition, it increases the agricultural production by the use of bio-slurry. Reducing dependence on imported petroleum and LPG are some of the national benefits of biogas. The biogas in Nepal has also been able to generate income through Clean Development Mechanism (CDM).[5] Global benefits include reduction of green house gas emission which contributes in minimizing climate change and global warming. Using the Biogas User Survey 2007/2008, we investigate and analyze these benefits. The Biogas User Survey 2007/2008 was conducted by Consolidated Management Services (P) Ltd. for AEPC, Nepal in 2008. The survey was conducted in 15

[4] The Biogas Support Program (BSP) was set up in 1992 as a joint venture between private companies recognized by ADB/N (government of Nepal) with the help of Netherlands Development Organization in Nepal (SNV/N), to promote the biogas program. German Government (KfW) also started funding the BSP since 1997. BSP was directly implemented by SNV/N until 2003. BSP-Nepal was established as an NGO in 2003. Since then BSP-N took over the implementation responsibility of BSP.

[5] The CDM is an arrangement under the Kyoto Protocol that allows industrialized (annex 1) countries with a GHG reduction commitment to invest in projects that reduce emissions in developing (non-annex 1) countries, as an alternative to more expensive emission reductions in their own countries. Under CDM a developing countries can sell carbon credits to industrialized countries.

Table 3
Reduction of smoke in the kitchen.

Type of stove	Biogas and improved			Biogas and traditional			All		
Changes	Hill	Terai	Total	Hill	Terai	Total	Hill	Terai	Total
Not reduced	9 (4.0)	3 (1.3)	12 (2.6)	2 (0.9)	0 (0.0)	2 (0.4)	11 (4.8)	3 (1.3)	14 (3.0)
Reduced to Some extent	39 (17.2)	4 (1.7)	43 (9.3)	1 (0.4)	9 (3.8)	10 (2.2)	40 (17.6)	13 (5.6)	53 (11.5)
Reduced drastically	158 (69.6)	121 (51.7)	279 (60.5)	18 (7.9)	97 (41.5)	115 (24.9)	176 (77.5)	218 (93.2)	394 (85.5)

Figures without and with parenthesis show the number of respondents and percentage respectively.

Table 4
Incidence of diseases among female, male, and children after biogas installation.

		Increased	Decreased	No change	No disease
Female	Eye infection	13 (2.9)	179 (39.7)	61 (13.5)	198 (43.9)
	Respiratory disease	7 (1.7)	102 (24.2)	64 (15.2)	249 (59.0)
	Cough	7 (1.7)	108 (26.0)	66 (15.9)	234 (56.4)
	Headache	15 (3.4)	183 (40.9)	79 (17.7)	170 (38.0)
Male	Eye infection	6 (1.6)	76 (19.7)	69 (17.9)	235 (60.9)
	Respiratory disease	4 (1.0)	59 (15.3)	66 (17.1)	256 (66.5)
	Cough	4 (1.0)	68 (17.5)	64 (16.5)	253 (65.0)
	Headache	5 (1.3)	78 (20.2)	71 (18.3)	233 (60.2)
Child	Eye infection	0 (0.0)	46 (23.2)	22 (11.1)	130 (65.7)
	Respiratory disease	0 (0.0)	40 (20.5)	22 (11.3)	133 (68.2)
	Cough	0 (0.0)	41 (21.1)	21 (10.8)	132 (68.0)
	Headache	0 (0.0)	43 (21.7)	22 (11.1)	133 (67.2)

Figures without and with parenthesis show the number of respondents and percentage respectively.

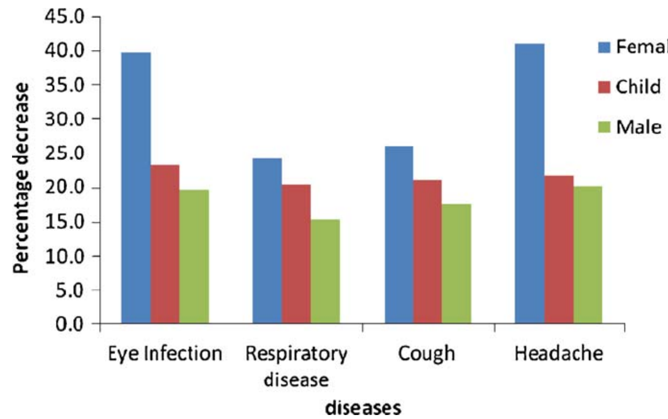


Fig. 2. Decrease in incidence of disease among male, female and child after the installation of biogas.

districts, which includes 10 districts from Hills and 5 districts from terai.[6]

4.1. Health benefits

Firewood and dung cake are used for cooking by most of the households in rural areas. Use of these traditional fuels produces obnoxious smoke and particulate that pollute the kitchen and causes several respiratory diseases. Indoor air pollution is one of the most direct physical health risks and exposure to biomass smoke increases the risk of respiratory diseases such as acute lower respiratory infection. It also increases the risk of bronchitis, asthma, lung cancer, ear infection etc [15]. Firewood burning, which is most common in Nepal, is the principal causes of indoor air pollution.

Biogas provides clean and smoke free energy unlike firewood. Thus installation of biogas helps reducing indoor air pollution and hence reduces the incidence respiratory diseases. Almost all households reported that biogas has helped improving the health. Table 3 represents the reduction of smoke in the kitchen after the installation of biogas plant. Out of 461 respondents, 85.5% (93.2% in terai and 77.5% in hills) reported that smoke was reduced drastically in the kitchen after the biogas installation. More than 11% (5.6% in terai and 17.6% in hills) of households reported that there was some reduction in smoke while 3% (1.3% in terai and 4.8% in hills) of household found no change.

Households were found to be using their pre-installation stove even after the installation of biogas. Some of the households were still using traditional stoves. Given the use of these multiple stoves, the reduction in smoke was felt accordingly. More households with improved stove reported the drastic reduction in smoke (60.5%) as compared to the households with biogas and traditional stove (25%).

[6] Terai is flat southern lowland region of Nepal which ranges from 100 to 500 m. The hill is the region, located in the middle part of the country, between the Himalayan and the Terai regions. It ranges from 500 to 3000 m.

We present in Table 4, the change in incidence of diseases after biogas installation. Most of the households reported a decrease in eye infection and headache after the installation of biogas. Among females who reported to have been suffering, it was found that there was drastic reduction in eye infections (39.7%) and headaches (40.9%) followed by remarkable reduction in cough (26%) and respiratory diseases (24%). Similarly, among males there was drastic reduction in eye infections (19.7%) and headaches (20.2%) followed by reduction in cough (17.5%) and respiratory diseases (15.3%). Children who were suffering also found reduction in eye infections, headaches, cough and respiratory diseases by 23.2, 21.7, 21.1 and 20.5% respectively.

It is worth mentioning and shown in Fig. 2, that, the reduction of the diseases was most effective among women and children. In developing country like Nepal, women do most of the cooking and spend more time than male counterparts in kitchen. Hence the effect of having smokeless and ash-less kitchen is felt mostly among women.

In addition to decrease in incidence of disease, an improved sanitation level is another health benefit. Installation of biogas motivates households to construct toilets which reduce the risk of several diseases such as worms, bacterial diseases and viral infections. In addition, there has been an increasing trend of connecting toilets to the biogas plant. This has helped improving the general sanitation condition around the households (Fig. 2).

4.2. Agricultural benefits

More than 80% of the households in Nepal are dependent in agriculture and manure is the major source of the fertilizer used in the country. The digested bio-slurry, a byproduct of the biogas has been proved to be the best fertilizer for farms in the rural households and almost all households with biogas apply bio-slurry on their land. The use of slurry has replaced the use of raw dung as well as chemical fertilizer. The use of slurry has helped increasing the agricultural production. A significant number of households found an increase in crop productivity after the slurry was used on

Table 5
Changes in crop productivity and income after the installation of biogas plant.

Land type	Terai			Hills			All		
	Increased	Decreased	Same	Increased	Decreased	Same	Increased	Decreased	Same
Khet	89 (44.5)	10 (5.0)	101 (50.5)	79 (45.9)	5 (2.9)	88 (51.2)	168 (45.2)	15 (4.0)	189 (50.8)
Bari	20 (51.3)	1 (2.6)	18 (46.2)	78 (52.3)	5 (3.4)	66 (44.3)	98 (52.1)	6 (3.2)	84 (44.7)
Kitchen Garden	72 (69.2)	0 (0.0)	32 (30.8)	64 (64.0)	0 (0.0)	36 (36.0)	136 (66.7)	0 (0.0)	68 (33.3)
Income	90 (45.5)	6 (3.0)	102 (51.5)	85 (38.8)	3 (1.4)	131 (59.8)	175 (42.0)	9 (2.2)	233 (55.9)

Figures without and with parenthesis show the number of respondents and percentage respectively.

the land. Table 5 shows that 68% of the household noticed an increase in crop productivity in their Kitchen Garden followed by Bari (52%) and Khet[7] (45%). Since Kitchen Gardens are the land nearest to the house, the maximum effect of slurry was found in Kitchen Garden. However, the effect of slurry is less in hills as compared to the terai.

Households not only reported an increase in crop productivity but also the end result of the use of slurry on their farms. The majority of the households reported an increase in income from the increased crop productivity. As shown in Table 5, 42% of households reported increase in income from agriculture production after the use of slurry.

4.3. Environmental benefits

Because of lack of other sources, firewood is the main source of energy for cooking, heating, and lighting. Being one of the major sources of energy, it is one of the major causes of deforestation in Nepal. At the same time deforestation has caused a fuel wood crisis. Moreover, use of firewood as fuel leads to increased emission of GHG which affects the environment locally and globally. Cooking and lighting are the most important use of biogas in Nepal and GHG emission reduction from reduced use of firewood for cooking has been one of the most remarkable successes of the biogas in Nepal. Biogas, not only supplies clean energy, but it also helps to improve environmental conditions by conserving forests.

In Table 6, we provide the sources of energy for cooking and lighting for pre-installation and post installation scenarios. Firewood is the major source for cooking before and after the biogas installation. However, significant reduction in firewood consumption was observed after the biogas installation. Table 6 shows that the consumption of firewood is reduced by 53%. Similarly the use of dung cake and saw dust was reduced by 63% and 99% respectively. It is worth mentioning that the use of electricity has not been reduced, as the major use of biogas has been observed in cooking.

Based on the reduction in firewood consumption, we estimate that a household with biogas saves about 250 kg of firewood per month. Thus saving of firewood from each household per year is about 3 tons. This reduction in demand for firewood helps to conserve forests. Similarly the saving of cow dung being directly burnt is 48 kg per month. According to Mendis and van Nes [16], emission coefficients for non sustainable fuel wood and kerosene are 1.5 tons CO_2e per ton and 2.5 tons CO_2e per 1000 l of kerosene. Based on these emission factors, a rural household with biogas reduces about 4.5 tons CO_2 being released in to the atmosphere each year. In other words, every biogas system in Nepal avoids nearly 4.5 tons of carbon emissions per year by reducing the use of firewood in the kitchen.

Table 6
Fuel used for cooking and lighting before and after the biogas installation.

	Before	After	Change	Percentage change
Fire wood (bhari/month)	11.82	5.54	6.28	53.13
Kerosene (l/month)	2.89	1.38	1.51	52.25
Agriculture residue (bhari/month)	4.74	2.62	2.12	44.73
Dung cake (kg/month)	76.13	27.94	48.19	63.30
LPG (cylinder/month)	3.48	1.18	2.30	66.09
Coal (kg/month)	17.15	9.70	7.45	43.44
Saw dust	56.76	0.53	56.23	99.07
Candle (NRs/month/HH)	13.79	19.59	−5.80	−42.06
Solar (% of HH having)	15.52	7.20	8.32	53.61
Electricity (unit/month/HH)	53.68	53.98	−0.30	−0.56
Others	15.00	15.50	−0.50	−3.33

In addition to health, agriculture and other environmental benefits, biogas in Nepal has started providing economic benefit from carbon trading since 2005. Nepal has already ratified Kyoto Protocol and is one of the non-annex 1 countries. Being one of the non-annex countries with low contribution of GHG, it has a potential of trading its reduced carbon emission with other developed (annex 1) countries. Since biogas is clean energy, it reduces the burning of biomass directly and thereby by reduces GHG emission and hence is used for carbon trading. It is the first GHG reductions project in Nepal under the CDM of the Kyoto Protocol. Two biogas projects of 19 396 plants constructed under phase IV have already been registered as CDM projects of Nepal. Nepal has been selling saved GHG emission through Voluntary Emission Reduction (VER)[8] managed by the World Bank [14]. Since 2007, Nepal started trading carbon emission with the World Bank at the rate of 7 USD per ton and recently the AEPC has signed an agreement with the bank to sell the carbon emission at 10.25 per ton. Nepal has already started earning over 600,000 USD per year through VER [14].

4.4. Workload reduction

Reduction of workload for women and children for the collection of firewood for cooking is one of the most significant benefits of biogas. Before biogas installation, women and children in the rural households had to spend most of their time collecting firewood and cooking. Women are the ones who spend most of their time doing household activities such as livestock caring, fetching water, firewood collection, dung preparation for cooking, fodder collection for livestock, cooking food, etc. After the biogas installation, women and children have been able to spend their saved time in more productive works such as education and other social activities. Table 7 shows the time spent on different activities before and after the biogas installation.

[7] Khet, Bari and Kitchen Garden are different categories of lands based on the types of cropping and closeness to the house in Nepal. Khet refers to lowland which is predominated by rice-based pattern such as rice, wheat etc. Bari is the land around the house where maize based cropping dominates. Kitchen Garden is the land closest to the house where households grow vegetables in general.

[8] The Protocol allows developed countries to achieve their targets through any of the three mechanisms—Emission Trading (ET), Joint Implementation (JI) and CDM. VER is trading deal which is made between the country and a private company which wants to buy the carbon credits to offset its own emissions.

Table 7
Reduction in time spent by female after biogas plant installation.

Activities	Time spent before biogas plant installation (min/day)	Time spent after biogas plant installation (min/day)	Saved time (min/day)
Livestock caring	174.2	177	−2.8
Fetching water	47.5	70	−22.5
Feeding biogas plant	0	29.7	−29.7
Firewood collection/dung cake preparation	224.8	143.3	81.5
Fodder collection	103.6	104.3	−0.7
Cooking	140.4	97.5	42.9
Cleaning utensils	55.43	30.4	25.03
Total balance	745.93	652.2	93.73

Women in rural a household spend almost 12 h a day for household activities such as livestock caring, firewood collection, cooking, fodder collection and cleaning utensils. Prior to the biogas installation, women in a rural household used to spend more than 3.75 h for firewood collection/dung cake preparation which is significantly reduced to 2.38 h after biogas installation. Thus, biogas reduces the amount of time a women spends collecting firewood and preparing dung cake by 1.36 h a day. Similarly, biogas stoves reduce time spent on cooking by three forth of an hour. In total, a biogas saves 1.56 h per day, which can be utilized in various other activities. The survey also collected data on utilization of saved time which we report in Table 8.

Most of the saved time was used in recreation activities, social work, income generating activities and reading. Thirty two percent (male—37% and female—26%) reported that they used the saved time to watch television and listening the radio. Similarly, 27% (male—23% and female—33%) reported that they were able to spend more time on social and community works. Most important, 23% of male and 28% of female (25% in total) reported that they spent the saved time on income generating activities. Although not so high, a remarkable fraction of population (11.5%) used their saved time for reading.

4.5. Women empowerment

Since the use of biogas reduces the time for several household activities significantly, women have benefited the most from the installation of the biogas plant. In other words, women are prime beneficiaries of the biogas installation.

As shown in Table 9, 33% of women spent their saved time in social and other community activities. This not only increases women's participation in social works but also contribute significantly to community development. Most of the women utilized their saved time by participating on mother's groups.[9] Almost half of the women (57% from hills and 49% from terai) participated in mother's group activities. Similarly, about one third of the total population of women participated in co-operatives. Forest user group and youth clubs are some other social communities where women were found to spend their saved time.

Table 8
Utilization of saved time in various activities.

Activities	Male	Female	All
Attending adult literacy	29 (4.8)	8 (1.7)	37 (3.4)
Recreation/watching TV/listening to radio	223 (36.9)	123 (25.9)	346 (32.1)
Reading (book, story, magazine etc)	69 (11.4)	55 (11.6)	124 (11.5)
Social/community work	141 (23.3)	154 (32.5)	295 (27.3)
Income generating activities	140 (23.1)	132 (27.8)	272 (25.2)
Others	3 (0.5)	2 (0.4)	5 (0.5)

Figures without and with parenthesis show the number of respondents and percentage respectively.

Table 9
Women's participation in local social services after biogas plant installation.

Activities	Hills	Terai	Total
Mother's group	156.0 (57.1)	121.0 (48.8)	277.0 (53.2)
Cooperatives	78.0 (28.6)	95.0 (38.3)	173.0 (33.2)
Forest user group	32.0 (11.7)	25.0 (10.1)	57.0 (10.9)
Youth club	7.0 (2.6)	7.0 (2.8)	14.0 (2.7)

Figures without and with parenthesis show the number of respondents and percentage respectively.

4.6. Employment generation

Biogas has evolved as a different market in Nepalese economy and resulted in additional employment generation. Job creation, by generating substantial skilled as well as unskilled employment during the process of construction and other related activities is another benefit of biogas in Nepal. About 95% of constructed plants are operational. There are 16 biogas appliances manufacturing workshops. Moreover, 167 micro finance institutes are engaged in biogas and mobilizing loan from AEPC's Biogas Credit Fund. In total, the biogas industry has been able to generate 11 000 jobs. In addition, about 1 080 000 persons are directly benefited by the technology [14].

5. Challenges and future of biogas in Nepal

There are many factors behind the acceptance and success of biogas in Nepal. Subsidies from the government, increased crop productivity, improvement in quality of life, improved health and saved time for women are some of the major factors. Subsidies have been one of the several reasons for the attraction of biogas installation. But, biogas cannot sustain itself with subsidies forever. This raises the question of sustainability. However, biogas can become self sustaining if CO_2 saved from it can be sold at rate of USD 5 per tCO_2 [8]. Thus for the long run sustainability, more work needs to be done in carbon trading so as to make carbon financing as a sustainable source for biogas.

Given the economic status of rural households, the family sized biogas is still costly for poor households and these households are excluded from the benefit of the subsidies. There is need of more research and development (R&D) so that the cost can be reduced and the technology is made affordable for the poor households. Moreover, cost could be one reason but, there are other factors that influence the demand such as awareness, availability of loan etc. Thus, factors that affect the demand need to be identified so that the demand for the technology can be increased.

Biogas in Nepal is focused mainly in family sized plants. It could potentially be applied to communities and for municipal waste recycling. Until now, with some exceptions, cattle dung has been used primarily as an input for the biogas. There has been limited use of biogas for kitchen waste, municipal waste and slaughter house waste, but not on a large scale. Use of other alternative biodegradable feedstocks such as municipal waste should be encouraged and promoted. This could be an effective option for disposing and recycling municipal waste. Bio-slurry has proved to be an effective fertilizer but there are some health risks associated with its use. More R&D is required for the proper storage and application of bio-slurry to minimize the health risks.

Studies have shown that biogas can be bottled and used for transportation and electricity generation. Thus, some of future

[9] Mother's Group is a voluntary group of adult women in a community that works on wide range of community welfare activities such as health, education, income generating activities etc.

potential of biogas which have not been explored and practiced in Nepal are bottling of biogas and its use for transportation and electricity generation.

6. Conclusions

Biogas, one of the most successful models of RETs in Nepal, has proved to be successful in uplifting the socio-economic status of its users because of multiple benefits it provides to the households, community and the country. Health, environmental and agriculture benefits are some of the important local benefits. Similarly, by reducing workload for household activities, the technology has helped to empower women and children. In addition, by reducing GHG emission, the technology also helps to mitigate climate change.

There is huge potential of biogas and opportunities are open, but not without challenges. Despite the attractive subsidies, the technology has not been able to reach to those who really need it. More work is required for the expansion and sustainability of the technology. More attention should be given towards the rural household who are deprived of electricity especially, in mountainous region. In addition, it is time to move beyond household activities and apply the technology to more expanded activities such as municipal waste and other biodegradable sources. Municipal waste, poultry industry waste, fish industry waste and slaughter house waste are some potential options. It needs more systematic and comprehensive study supported by R&D. This will help to produce biogas in large scale and can be used for other large-scale activities such as transportation, electricity generation, etc.

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